instruction," under Art. 115 of the Code, unless it have a proper supply of casts and models for drawing.

II. As to classes under the Science and Art Department, and grants by the Department:—(*a*) That school boards have power to establish, conduct, and contribute to the maintenance of classes for young persons and adults (being artisans) under the Science and Art Department. That, in localities having no school board, the local authority have analogous powers.

IV. Secondary and technical instruction:—(*a*) That steps be taken to accelerate the application of ancient endowments, under amended schemes, to secondary and technical instruction. (*b*) That provision be made by the Charity Commissioners for the establishment, in suitable localities, of schools or departments of schools in which the study of natural science, drawing, mathematics, and modern languages shall take the place of Latin and Greek. (*c*) That local authorities be empowered, if they think fit, to establish, maintain, and contribute to the establishment and maintenance of secondary and technical (including agricultural) schools and colleges.

V. Public libraries and museums:- (*b*) That museums of art and science and technological collections be open to the public on Sundays.

COTTERILL'S "APPLIED MECHANICS"

Applied Mechanics: an Elementary General Introduction to the Theory of Structures and Machines. By James H. Cotterill, F.R.S. (London: Macmillan and Co., 1884.)

AMONG the many indications of the increasing interest which technical education, in its widest extent, now calls forth, one of the most conspicuous is the production of manuals and text-books on the various subjects with which it deals. Amongst these there is none which is more important than Applied Mechanics, and, at the same time, we may add that there is none which has been more in need of a good elementary text-book. The great works on the subject by Rankine and Moseley are not adapted for elementary teaching, involving mathematical processes beyond the power of a beginner, and thus it has come to pass that a country renowned for its engineering triumphs and for the excellence of many treatises dealing with the practical applications of applied mechanics, has hitherto possessed no book devoted to an exposition of its principles and suitable for educational purposes. Those persons, therefore, who are familiar with Prof. Cotterill's work on the Steam-Engine will have looked forward with much interest to the publication of his long-advertised book on "Applied Mechanics." Its recent appearance we venture to think has in no sense disappointed their expectation, for it bears on every page evidence that its author has not only studied and become intimately acquainted with his subject, but that he possesses the rare faculty of having learned by experience in teaching, the best way of presenting a subject so as to diminish its difficulties and make rough places smooth for the footsteps of the beginner. By assuming a knowledge on the part of the reader of the elements of theoretical mechanics he has been enabled to devote the whole of this large volume to the exposition of the more complicated science, in which the principles of the former are applied to the problems of construction presented to the architect and the engineer. The treatise is strictly elementary in its methods, the mathematics used being, almost without exception, of the simplest kind, and many results, which have usually been obtained by complicated investigations, are here arrived at by neat and elegant simple processes. The style of reasoning adopted is also very successful, being neither too diffuse, nor, on the other hand, so much compressed as to puzzle and dishearten the beginner by gaps in the reasoning which his mental capacity is not able to bridge. This is particularly evident in the earlier parts of the book. Towards the end, in the section on Hydraulics and Pneumatics, we think that sufficient fulness of explanation has hardly been furnished, in dealing with the application of the principles of Energy, Momentum and Moment of Momentum, to Fluids, and especially in the case of Hydraulic Motors, to enable the student to grasp the subject without a frequent reference to some of the text-books which the author names.

Another point of supreme importance in which Prof. Cotterill's treatment leaves nothing to be desired, is the manner in which he has attained the aim he set before himself of endeavouring "to distinguish as clearly as possible between those parts of the subject which are universally and necessarily true, and those parts which rest on hypotheses more or less questionable." In Applied Mechanics it frequently, we may say usually, happens that, owing to various disturbing causes, exact investigations are either impossible to effect or useless from a practical point of view when carried out, owing to the complexity of the results, and we are therefore led either to adopt results derived from experiments conducted under the guidance of a roughly approximate theory or obliged to rely on experiment alone and, in studying the subject, it is of prime importance that the exact limitations should be stated under which the formulæ and rules given can with certainty be applied. This exact knowledge is necessary not only in the interests of science, but also in many practical applications involving the security of life or property. Many writers on this subject have slurred over or insufficiently estimated the importance of an exact statement of conditions and limitations, and consequently we are glad to recognise and point out the thorough and satisfactory way in which this has been attended to by the author.

The book is divided into five parts, of which the first is devoted to "The Statics of Structures." In this section there is not room in an elementary work for much new matter, but we may point out as specially good the manner in which the communication of stress from part to part of a compound frame is traced out. The relation and interdependence of the primary and secondary trusses of such a structure is here indicated more clearly than in any work with which we are acquainted.

The principal peculiarity of the book consists in the complete adoption of Reuleaux's Kinematic Analysis as the basis of the description and treatment of machines, both in their kinematic and kinetic aspects. In this system a machine is regarded as consisting "of a number of parts so connected together as to be capable of moving relatively to one another in a way completely defined by the nature of the machine. Each part forms an element

of two consecutive pairs, and serves to connect the pairs so that the whole mechanism may be described as a chain, of which the parts form the links. Such a series of connected pieces is called a kinematic chain." It is in this mode of regarding the component parts of a machine and in the consequences that flow from it that the peculiarities of the modern system consist. A valuable feature of this work is the series of curves of velocity given for different mechanistic combinations, especially those derived from the slider-crank chain. The special use of such curves is that the varying motion of different parts is exhibited to the eye, which is thus enabled to realise its changes during the cycle in a complete way which would otherwise be difficult, if not impossible. Of the large and intricate subject of the Teeth of Wheels only a sketch is given, which a student would need to supplement by extensive reference to other books in order to understand.

In the Part on the Dynamics of Machines we find the chapter on "The Dynamics of the Steam-Engine" the best in the book. The mode of constructing curves of crank effort of two kinds is shown, and the results given in different cases for two cranks at right angles and for three cranks at angles of 120°, and these curves are used to determine the fluctuation of energy in a complete revolution. This last is expressed in terms of the total energy as a fraction which, in the case of a three-throw crank with connecting rod equal in length to six cranks is as low as ·0084. A method is afterwards given by which to obtain similar results from any indicator diagram.

The chapter on Friction contains a complete *résumé* of modern experiments on friction with an investigation by both exact and approximate methods of the efficiency of mechanism when friction is considered.

The Principle of Work is assumed throughout the book, being regarded as "a fundamental mechanical principle continually verified by experience, and a great many results are thus arrived at in the simplest way. One very interesting example is got by applying this principle (in the form known as the principle of virtual velocities) to the determination of the bending moment in the case of a loaded beam. Nowhere has the author been more successful in his simple mathematical treatment than in the chapters which deal with the strength and deflection of beams, and the power possessed by a combination of the mathematical and the graphical methods could hardly be shown more strongly than by the proof, given without the use of the calculus, of the most general form of Clapeyron's Theorem of Three Moments.

The fundamental theorems of the theory of elasticity are presented in an equally simple and elementary way. In describing the behaviour of matter strained beyond the elastic limit, a brief account is given of the mode of rupture of different classes of bodies when loaded so as to exceed that limit, and the information here furnished, as in all the other descriptive parts of the book, is brought up to the level of our present experimental knowledge.

The concluding chapters treat of the transmission and conversion of energy by fluids, and contain a brief account of the ordinary propositions in hydraulics and pneumatics, together with the outlines of the theories of hydraulic motors and of heat-engines. The flow of liquids and gases through pipes is also dealt with.

The aim of the book excludes any detailed description of machines, although the drawings of machines are, as a rule, working drawings, the desire being to elucidate the principles and theory of machines in general, but incidentally much valuable descriptive matter is introduced, and the illustrations are in all cases derived from actual machines and structures. Thus, among other valuable topics of practical interest we have an exposition of the theory of fly-wheels, centrifugal regulators, dynamometers, the balancing of machines, and of impact, this last being illustrated, amongst other examples, by the action of a gust of wind on a vessel.

At the end of each chapter we find a selection of well devised and admirable examples, most of them so framed as either by way of illustration to bring into prominence particular parts of the text or to show the influence in special cases of modifying causes. This collection, which must have taken much time and trouble to prepare, is by no means the least useful part of the book, the value of which is yet further increased by the full list of authorities for reference which is appended to each chapter, which will assist the student in extending his studies in any special direction.

This book may be recommended not only for the admirable mode of treatment of that which it contains, but also for the exclusion of that which does not find a place there. The same knowledge of the needs of a reader beginning the study of applied mechanics which has led to the selection and arrangement of the topics introduced, has led to the omission of other parts which, though useful and interesting in themselves, are not necessary to be mastered on a first approach to the subject. We could wish that the proofs had been more carefully revised, so that a number of, for the most part trifling, though tiresome, errata might have been corrected. A careful perusal of the volume leads us to express almost unqualified praise of this latest addition to the English literature of applied mechanics.

J. F. MAIN

OUR BOOK SHELF

Graphic and Analytic Statics in Theory and Comparison. By Robert Hudson Graham, C.E. (London: Crosby Lockwood and Co., 1884.)

THIS is an extensive treatise for the use of engineers, the distinguishing feature of it being that graphic and analytic methods are both employed. The first part (30 pp.) deals with the principles of graphic statics, and contains some well-chosen examples of the beautiful method of reciprocal figures. The second part (50 pp.) treats of the stresses of roofs and bridge structures, both methods being employed. The third part (290 pp.), which for some reason is called comparative statics, consists of eight chapters, the subjects of which are direct stress (elongation of bars, &c.), couples, composition of forces, centre of gravity, moments, straight beams and girders, solid girders in equilibrium, and wind pressures. Throughout the book there are interspersed collections of valuable exercises with their results.

The most manifest defect of the work is a prevailing inaccuracy of expression. With such a subject this is quite inexcusable, and is sure to be found excessively trying to the patience of a student. It is not at all due to want of mathematical knowledge on the author's part, so that, as might be expected, he is perfectly unconscious of it. Ludicrously so indeed; for in the preface he tells us